Differentiated duopoly under vertical relationships with communication costs‡

by

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Abstract

Platform sharing across manufacturers has recently become common practice in the automobile industry. Its important objective is to reduce procurement costs by taking advantage of the commonality of components, but this often reduces the degree of product differentiation. We investigate this trade-off through analyzing a model that incorporates manufacturer-supplier relationships with communication costs into a standard differentiated duopoly model, and find an interesting inverse relationship between the advantage of platform sharing and the costs for manufacturers to communicate with their potential suppliers. The result suggests that the information-technology revolution could be a reason for the recent prevalence of platform sharing in the automobile industry, and predicts that similar phenomena would prevail in various other industries as the IT revolution makes further progress. We then consider an extension of our model that incorporates an option for the manufacturers to jointly establish a B2B electronic marketplace in order to reduce their communication costs, and explore its welfare implications. Although the joint establishment of an e-marketplace could be viewed as an anticompetitive activity, we find that in our framework it increases welfare.

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1 Introduction

Platform sharing across manufacturers has recently become common practice in the automobile industry, where platform means the core framework of cars that includes the floorpan, drive train, and axles (see, e.g., Tierney et al. (2000) for platform sharing between Renault and Nissan, and Corbett and Wielgat (2000) for platform sharing between Fiat and GM). An important objective of platform sharing is to reduce procurement costs by taking advantage of the commonality of components. According to Tierney et al. (2000), Renault's chairman mentioned, "We will have common platforms and common engines with Nissan, which means we are giving suppliers increased volumes". On the other hand, the use of differentiated components is one of the most important means by which downstream firms differentiate their products (Pepall and Norman (2001)). Robertson and Ulrich (1998) point out, as an example, that the instrument panels for two different automobile models lose more and more distinctiveness as more and more parts are shared between the two models.

This paper analyzes the trade-off between commonality of components and distinctiveness of products. We consider a model that incorporates manufacturer-supplier relationships with communication costs into a standard differentiated duopoly framework (due to Dixit (1979) and Singh and Vives (1984)). The degree of product differentiation is endogenously determined in our model. Consider an industry consisting of two manufacturers who compete against each other by producing differentiated products. In order to produce a product, each manufacturer must procure a component (call it a part) from a supplier. There is a free entry of suppliers, where each supplier incurs a fixed cost to enter. Each supplier has a constant marginal cost of production, which has a random component. The two manufacturers jointly determine whether to use a common (or similar) part or distinctive parts, and then suppliers make entry decisions. Upon entry, each supplier privately observes its own constant marginal cost. Each manufacturer then determines the number of suppliers with which it will exchange detailed information on requirements such as timeliness and flexibility of delivery, product design, and allowance for defection rates, where it incurs a fixed amount of communication cost per supplier. Each manufacturer then chooses one supplier through a procurement auction.

The model captures the trade-off between commonality of components and distinctiveness of products by assuming that the use of a common (or similar) part reduces the degree of product differentiation. We label the use of a common part as "platform sharing". Under platform sharing, one supplier can serve both manufacturers. On the other hand, one supplier can serve at most one manufacturer if they do not share a platform, because each supplier must choose one distinctive part to specialize in.

We find that, under platform sharing, each manufacturer can choose a supplier from a larger number of potential suppliers, which in turn lowers each manufacturer's expected price for procurement. To understand the logic, let us suppose for now that the communication cost is zero so that each manufacturer communicates with all relevant entrants. Under platform sharing, an entrant with the lowest cost wins both procurement auctions and sells a common part to both manufacturers. On the other hand, if the manufacturers do not share a platform, an entrant with the lowest cost among competitors can sell a distinctive part to only one manufacturer. In both cases, in equilibrium each entrant's post-entry expected profit is equal to the fixed cost of entry because of the zero profit condition due to free entry. This in turn means that, in equilibrium, competition among relevant entrants is tougher under platform sharing, because the winner can serve both manufacturers. The advantage of this, from the manufacturers' standpoint, is that each manufacturer can choose a supplier from a larger number of relevant entrants under platform sharing.

The result is that the two manufacturers share a platform if the reduction of product differentiation due to platform sharing is relatively small, and each manufacturer's communication cost per supplier is relatively small as well. Here we observe an interesting inverse relationship between the advantage of platform sharing and the level of communication costs. As described above, the advantage of platform sharing in our framework is that each manufacturer can lower its expected procurement costs by choosing a supplier from a larger number of potential suppliers. Since each manufacturer must incur a fixed amount of communication costs in order to exchange detailed information with a potential supplier, the advantage of platform sharing decreases as the level of communication costs increases.

Concerning welfare consequences of platform sharing, we find that, if the two manufacturers choose to share a platform, the decision increases consumer surplus as well as total surplus. Platform sharing reduces the level of product differentiation, which in turn intensifies competition between the two manufacturers. We find that, from the consumers' standpoint, the former negative effect of platform sharing (reduction of product variety) is offset by the latter positive effect (lower price due to intense competition) when platform sharing increases the manufacturers' profits. Then, noting that each supplier's expected profit is zero due to free entry, platform sharing increases the total surplus as well.

The rapid spread of electronic commerce, due to recent advances in information technology, is substantially changing the nature of manufacturer-supplier relationships. One important recent phenomenon is the formation of industry consortiums for establishing business-to-business (B2B) electronic marketplaces such as Covisint in the automobile industry, which can substantially reduce buyers' communication costs for exchanging detailed information with potential suppliers. For example, according to Covisint's web page[1], when procuring an intermediate product automobile manufacturers typically choose several potential suppliers and issue a Request for Quote (RFQ) that specifies detailed requirements on product

[1]http://www.covisint.com/solutions/proc/qm.shtml, visited July 9, 2002.

design, delivery and shipping terms, quality goals and so on, to which the potential suppliers respond. Frequently this process entails multiple rounds of review, collation and revision. In a case study presented on the web page, a Senior Buyer at General Motors commented, "Typically, much of the time during the sourcing process is in passing the documentation back and forth between the supplier and the buyer ... In order to clarify the information several rounds of document exchanges are necessary. This exchange takes up valuable sourcing time during an already short sourcing window." She then said, "With Covisint, we could exchange documents and revisions electronically ... The exchange of information was handled quickly and efficiently. I was able to spend more time on the value added portion of my job - analyzing the quote responses."[2]

In Section 4 we consider an extension of our model that incorporates an option for the two manufacturers to jointly establish a B2B electronic marketplace (e-marketplace) in order to reduce their costs for communicating with potential suppliers, and explore its welfare implications. The establishment of an e-marketplace could be viewed as an anticompetitive activity when accompanied by platform sharing, because it induces the manufacturers to reduce their procurement costs at the expense of reduced product variety. Our results show, however, that the establishment of an e-marketplace increases total surplus as well as consumer surplus, as long as the manufacturers compete in the product market.

This paper contributes to the theoretical analyses of product differentiation by endogenizing the degree of product differentiation, which is affected by the nature of inputs procured from upstream suppliers. Pepall and Norman (2001) recently made an important contribution to this unexplored area of research. They considered a model in which downstream manufacturers differentiate their products by using different combinations of differentiated

[2]See also, e.g., Kauffman and Walden (2001) and Lucking-Reiley and Spulber (2001) for related discussions.

inputs procured from upstream suppliers, and compared firms' profitability under several types of alliances across manufacturers and/or suppliers.

We make a contribution complementary to their work by addressing the trade-off between commonality of inputs and the degree of product differentiation, and exploring its implications on the nature of product-market competition and manufacturer-supplier relationships. Our model indicates an interesting inverse relationship between the advantage of platform sharing and the level of communication costs, which yields a prediction that phenomena similar to the platform sharing in the automobile industry would prevail in various other industries as the information-technology revolution makes further progress. Furthermore, an extension of our model described above makes a contribution to current antitrust investigations regarding B2B electronic marketplaces by proposing a theoretical framework for analysis.

The article is organized as follows. Section 2 presents a model that incorporates manufacturer-supplier relationships with communication costs into a standard differentiated duopoly model. Section 3 analyzes the model and explores its welfare consequences. Section 4 considers an extension of the model in which the downstream manufacturers have an option of jointly establishing a B2B electronic marketplace in order to reduce their costs for communicating with potential suppliers, and discusses its welfare implications. Section 5 concludes.

2 The model

We incorporate manufacturer-supplier relationships with communication costs into a standard differentiated duopoly model due to Dixit (1979) and Singh and Vives (1984). Consider an economy consisting of an industry with two manufacturers who compete against each other by producing differentiated products, and a competitive numeraire sector whose output is denoted q_0. There is a free entry of suppliers to the industry, where each supplier incurs a fixed cost $f > 0$ to enter. The manufacturers and the suppliers are risk neutral. Each manufacturer i (=1, 2) produces product i, and let p_i and q_i denote the price and the quantity of product i, respectively. There is a continuum of consumers of the same type, and the representative consumer's preferences are described by the utility function $U(q_1, q_2) + q_0$, where $U(q_1, q_2) = A(q_1 + q_2) - (q_1^2 + 2\gamma q_1 q_2 + q_2^2)/2$, $A > 0$, and $\gamma \in (0, 1)$. This yields linear inverse demands

$$p_1 = A - q_1 - \gamma q_2 \tag{1}$$

$$p_2 = A - q_2 - \gamma q_1. \tag{2}$$

The degree of product differentiation decreases as γ increases.

Each manufacturer i must procure one unit of an intermediate product (call it a part) from a supplier in order to produce one unit of product i. The two manufacturers jointly determine whether to use a common (or similar) part or distinctive parts (we label the use of a common part as platform sharing), and then suppliers make entry decisions. Each manufacturer then determines the number of suppliers with which it exchanges detailed information on requirements such as timeliness and flexibility of delivery, product design, and allowance for defection rates, where it must incur communication cost $z(\geq 0)$ per supplier (see Introduction for an illustration of the substance of such costs). Each manufacturer i's cost for producing q_i units of product i is given by μq_i + procurement costs, where μ denotes the constant marginal cost for production. We normalize μ to be zero. Communication in our model is similar to a "link" considered in a recent innovative analysis of networks by Kranton and Minehart (2001).[3]

[3]In their model, a buyer and seller must have a relationship, or "link", to exchange goods, where a link is anything that makes possible or adds value to a particular bilateral exchange. Buyers form links by incurring a fixed amount of cost per each link, then compete to obtain goods from their linked suppliers. Kranton and

We consider the four-stage game described below.

[**Stage 1**] The two manufacturers jointly determine whether or not to share a platform of their products. If they do not share a platform, each manufacturer i uses a distinctive part (call it part i) for producing product i, and the parameter γ is given by $\gamma = \gamma_0$, where $\gamma_0 \in (0, 1)$. On the other hand, if they share a platform, the two manufacturers use a common part, and the parameter γ is given by $\gamma = \gamma_0 + x$, where $x \in (0, 1 - \gamma_0)$. The manufacturers' decision becomes common knowledge. This specification captures a trade-off between commonality of parts and distinctiveness of products. That is, if the two manufacturers use a common part, the degree of product differentiation decreases by x.

[**Stage 2**] Suppliers make entry decisions. There is a free entry of suppliers, and each supplier incurs a fixed cost $f > 0$ if it enters. If the two manufacturers chose not to share a platform in the previous stage, each supplier must determine whether to specialize in part 1 or part 2; a single supplier cannot produce both part 1 and part 2. Suppliers' entry decisions become common knowledge. Each supplier s (=1, 2, ...) has a constant marginal cost of production given by $c_s = c - \epsilon_s$, where $c \in (0, A)$ and ϵ_s is a random variable. Assume that ϵ_s is identically and independently distributed according to a uniform distribution between 0 and $k \in (0, c)$. The realization of ϵ_s is *ex ante* unknown. If supplier s enters, it privately observes the realization of ϵ_s after the entry.

[**Stage 3**] Each manufacturer i determines the number of suppliers to communicate with, where each manufacturer i must incur a communication cost of $z (\geq 0)$ per supplier.

Minehart showed that buyers and sellers, acting strategically in their own self-interests, can form the link pattern (or network structures) that maximizes overall welfare.

Although related, our model is distinctively different from theirs. We explicitly model the strategic interaction between manufacturers (or buyers) in their product market and analyze, among other things, the relationship between the advantage of platform sharing and the level of communication cost.

[**Stage 4**] Each manufacturer i simultaneously and non-cooperatively announces p_i, and consumers make purchase decisions. Each manufacturer i then conducts a procurement auction among n_i suppliers it communicated with at the previous stage, and purchases parts from one supplier. The auction is designed by each manufacturer i so as to maximize its expected profit. Each manufacturer i then produces and delivers product i.

3 Analysis

The game described above has two Stage 2 subgames. One is the subgame in which the two manufactures did not share a platform at Stage 1, while the other is the one in which they shared a platform. We consider the symmetric Subgame Perfect Nash Equilibria (SPNE) of each subgame, and characterize an equilibrium of the entire game. We consider an equilibrium in which the two manufacturers jointly decide whether or not to share a platform at Stage 1 so that each manufacturer's expected profit in the subsequent symmetric SPNE outcome is maximized. We will first outline the analysis of the model using backwards induction, and then present the main results in Propositions 1 and 2. Throughout the analysis, we make the following assumptions:

Assumption 1: $f < \frac{1}{(1+\gamma_0)(2-\gamma_0)}(A-c)\frac{k}{2}$.

Assumption 2: $z < \frac{1-(\gamma_0+x)}{(1+\gamma_0+x)[2-(\gamma_0+x)]^2}(A-c)^2 \equiv \bar{z}$.

Assumption 3: $A > c + \frac{2+k-(\gamma_0+x)}{1-(\gamma_0+x)}$.

Assumption 1 implies that the entry cost for suppliers is small enough so that at least one supplier enters in order to supply parts to each manufacturer i in equilibrium, and Assumption 2 says that the communication cost is low enough so that each manufacturer communicates with at least one supplier in equilibrium. Also, Assumptions 1-3 together imply that each manufacturer i always purchases parts through a procurement auction in equilibrium. These assumptions are not crucial for our results, but simplify the analysis and the statement of propositions. Note, all proofs are in the Appendix.

Consider a Stage 4 subgame in which the two manufacturers did not share a platform at Stage 1, and at Stage 3 each manufacturer i communicated with $n_i(\geq 1)$ suppliers who specialized in part i at Stage 2. Suppose that the two manufacturers announced the prices (p_1, p_2) at Stage 4, which determines the demand for each product i (denoted $q_i \geq 0$). The standard result of auction theory indicates that, in an optimal procurement auction, each manufacturer i procures q_i units of part i from a supplier who realized the lowest production cost among n_i suppliers it communicated with, and that the expected price of the part is equal to the second lowest realization of the production cost among n_i suppliers if $n_i \geq 2$ and c if $n_i = 1$ (see, e.g., Myerson (1981)).[4] The expected value of each manufacturer i's constant marginal cost for production is then $c - \frac{n_i - 1}{n_i + 1}k \equiv \tilde{c}_i$.[5] Noting that the two manufacturers correctly anticipate this, the SPNE outcome of the Stage 4 subgame is characterized by the following:

$$p_i^* = \frac{(1-\gamma)(2+\gamma)A + 2\tilde{c}_i + \gamma\tilde{c}_j}{4-\gamma^2} \equiv p_i(\gamma, n_i, n_j), \tag{3}$$

$$q_i^* = \frac{(1-\gamma)(2+\gamma)A - (2-\gamma^2)\tilde{c}_i + \gamma\tilde{c}_j}{(1-\gamma^2)(4-\gamma^2)} \equiv q_i(\gamma, n_i, n_j), \tag{4}$$

$$\pi_i^* = \frac{[(1-\gamma)(2+\gamma)A - (2-\gamma^2)\tilde{c}_i + \gamma\tilde{c}_j]^2}{(1-\gamma^2)(4-\gamma^2)^2} - n_i z \equiv \pi_i^m(\gamma, z, n_i, n_j), \tag{5}$$

where $i, j = 1, 2, i \neq j$, $p_i^*(q_i^*)$ denotes equilibrium price (quantity) of product i, π_i^* denotes manufacturer i's expected profit in equilibrium, and $\gamma = \gamma_0$.

[4]More precisely, Assumption 3, along with Assumption 1 and 2, guarantees that each manufacturer i purchases q_i units of part i with probability one through a procurement auction in equilibrium. See Appendix for details.

[5]The expected value of lth order statistic from a uniform $(0, 1)$ is $\frac{l}{n+1}$.

A supplier with whom manufacturer i communicated at Stage 3 wins the procurement auction with probability $\frac{1}{n_i}$ and, if it wins, it sells $q_i(\gamma, n_i, n_j)$ units of part i to manufacturer i. The expected price of part i is $c - \frac{n_i - 1}{n_i + 1}k$ and the expected constant marginal cost of the winning supplier is $c - \frac{n_i}{n_i+1}k$. Hence, each supplier's expected profit is $q_i(\gamma, n_i, n_j)\frac{k}{n_i+1}\frac{1}{n_i} - f$, which is equal to

$$\frac{(1-\gamma)(2+\gamma)A - (2-\gamma^2)\tilde{c}_i + \gamma\tilde{c}_j}{(1-\gamma^2)(4-\gamma^2)} \frac{k}{n_i + 1}\frac{1}{n_i} - f \equiv \pi_i^s(\gamma, n_i, n_j) - f, \tag{6}$$

where $\gamma = \gamma_0$.

Now consider a Stage 4 subgame in which the two manufacturers shared a platform at Stage 1, and at Stage 3 each manufacturer i communicated with $n_i(\geq 1)$ suppliers. Through an analogous procedure, we find that the SPNE outcome of the Stage 4 subgame is characterized by $p_i^* = p_i(\gamma_0 + x, n_i, n_j)$, $q_i^* = q_i(\gamma_0 + x, n_i, n_j)$, and $\pi_i^* = \pi_i^m(\gamma_0 + x, n_i, n_j)$, where $p_i(\cdot,\cdot,\cdot)$, $q_i(\cdot,\cdot,\cdot)$, and $\pi_i^m(\cdot,\cdot,\cdot)$ are as defined in (3)-(5) above. Also, a supplier's expected profit in the SPNE outcome is $\pi_i^s(\gamma_0 + x, n_i, n_j) - f$ if it is communicated by manufacturer i only, and $\pi_1^s(\gamma_0 + x, n_1, n_2) + \pi_2^s(\gamma_0 + x, n_2, n_1) - f$ if it is communicated by both manufacturers.

In what follows we proceed our analysis by treating the number of suppliers as a continuous variable. Lemma 1 below identifies each manufacturer i's expected profit in the symmetric SPNE outcome of a Stage 2 subgame. We define n_c and n_d by

$$2\pi_i^s(\gamma_0 + x, n_c, n_c) - f = 0, \pi_i^s(\gamma_0, n_d, n_d) - f = 0. \tag{7}$$

Here, n_c is the number of suppliers that enter in equilibrium if the communication cost is zero and the two manufactures share a platform (subscript c is for common part), and n_d is the number of suppliers that enter and specialize in part i (=1 or 2) if the communication cost is zero and the two manufacturers do not share a platform (subscript d is for distinctive part). We also define $n(\gamma, z)$ by

$$n(\gamma, z) = \arg\max_{n_i \geq 1} \pi_i^m(\gamma, z, n_i, n(\gamma, z)), \tag{8}$$

where $n(\gamma, z)$ is the number of suppliers each manufacturer communicates with in the symmetric SPNE outcome of the Stage 3 subgame in which a sufficiently large number of suppliers entered in the previous period. In the proof of Lemma 1, we show that n_c, n_d and $n(\gamma, z)$ are all uniquely determined by (7) and (8) above.

Lemma 1: Let $\tilde{n}_c(z) \equiv Min[n(\gamma_0 + x, z), n_c]$ and $\tilde{n}_d(z) \equiv Min[n(\gamma_0, z), n_d]$. In the symmetric SPNE outcome of a Stage 2 subgame, each manufacturer i's expected profit is $\pi_i^m(\gamma_0 + x, z, \tilde{n}_c(z), \tilde{n}_c(z))$ if the two manufacturers shared a platform at Stage 1, and $\pi_i^m(\gamma_0, z, \tilde{n}_d(z), \tilde{n}_d(z))$ otherwise.

To understand Lemma 1, consider a Stage 2 subgame in which the two manufacturers shared a platform at Stage 1. Let the communication cost z be equal to zero for now. Each manufacturer then communicates with all n suppliers that enter at Stage 2, and hence each supplier's expected profit is $2\pi_i^s(\gamma_0 + x, n, n) - f$. Since suppliers anticipate this, $n_c(\geq 1)$ suppliers enter in equilibrium because $2\pi_i^s(\gamma_0 + x, n_c, n_c) - f$ is equal to zero by the definition of n_c. This continues to hold as long as the communication cost z is low enough such that $n(\gamma_0 + x, z) \geq n_c$ holds. However, if $n(\gamma_0 + x, z) < n_c$ holds, the communication cost is so high that each manufacturer communicates with only $n(\gamma_0 + x, z)$ suppliers, which is less than the number of suppliers that enter. This implies that each manufacture's expected profit in equilibrium is $\pi_i^m(\gamma_0 + x, z, \tilde{n}_c(z), \tilde{n}_c(z))$. A similar logic holds for the Stage 2 subgame in which the two manufacturers did not share a platform at Stage 1.

We now consider the equilibrium of the entire game. Lemma 1 implies that in the equilibrium the two manufacturers choose to share a platform at Stage 1 if and only if

$\pi_i^m(\gamma_0 + x, z, \tilde{n}_c(z), \tilde{n}_c(z)) > \pi_i^m(\gamma_0, z, \tilde{n}_d(z), \tilde{n}_d(z))$ holds.

Proposition 1: For any given parameterization, there exists a unique value $\bar{x} \in (0, 1-\gamma_0)$ such that, in the equilibrium,

(i) if $x > \bar{x}$, the two manufacturers do not share a platform.

(ii) if $x < \bar{x}$, there exists a unique value $z^* \in (0, \bar{z}]$ such that the two manufacturers share a platform if and only if $z < z^*$. There exists a range of parameterizations in which $z^* < \bar{z}$ holds.

To understand Proposition 1, let the communication cost z be equal to zero for now. The proposition then tells us that the two manufacturers share a platform if the reduction of product differentiation due to platform sharing, captured by x, is relatively small.

The result is due to the trade-off between the commonality of parts and the distinctiveness of products. Note that each manufacturer communicates with all relevant suppliers because the communication cost z is zero. Then, under platform sharing, a supplier with the lowest realization of the production cost sells the common part to both manufacturer 1 and 2 by winning both procurement auctions. In contrast, if the two manufacturers do not share a platform, a supplier can sell a distinctive part to at most one manufacturer. Hence a supplier's expected profit, provided that it wins the procurement auction(s), is higher under platform sharing. This implies that the number of suppliers that enter under platform sharing is greater than the number of suppliers that enter and specialize in part i under non-platform sharing. That is, under platform sharing, each manufacturer can choose a supplier from a larger number of potential suppliers, which in turn lowers each manufacturer's expected price for procurement. This is the advantage of platform sharing. On the other hand, platform sharing reduces the extent of product differentiation between the two manufacturers, which lowers each manufacturer's profitability by intensifying their competition in the product market. If the latter effect, captured by parameter x, is relatively small, the two manufacturers share a platform.

Now let us allow the communication cost z to take positive values. Our model suggests an interesting relationship between platform sharing and communication costs. That is, Proposition 1 says that, given $x < \bar{x}$, the two manufacturers share a platform if and only if the communication cost z is low enough. This is because, as described in the previous paragraph, the advantage of platform sharing is that each manufacturer can choose a supplier from a larger number of potential suppliers. Since each manufacturer must pay communication cost z in order to exchange detailed information with a potential supplier, the advantage of platform sharing decreases as the communication cost increases and the two manufacturers do not share a platform if the communication cost is greater than a threshold z^*.

It is widely recognized that recent advances in information technology (IT revolution) can substantially reduce communication costs among firms. Our model then suggests that the IT revolution can be a reason for the recent prevalence of platform sharing in the automobile industry, and predicts that similar phenomena would prevail in other industries as the IT revolution makes further progress. In the next section, we will explore an extension that incorporates the IT revolution in our framework.

Next we analyze welfare consequences of platform sharing. In Proposition 2, we compare the Stage 2 subgame in which the two manufacturers shared a platform at the previous stage and the Stage 2 subgame in which the manufacturers did not share a platform.

Proposition 2: Let CS_c (CS_d) denote the consumer surplus in the symmetric SPNE outcome of the Stage 2 subgame in which the two manufacturers shared (did not share) a platform at the previous stage, and define TS_c and TS_d analogously for expected total surplus. Then, $CS_c > CS_d$ and $TS_c > TS_d$ if $x < \bar{x}$ and $z < z^*$.

From Proposition 1 we know that the two manufacturers choose to share a platform if $x < \bar{x}$ and $z < z^*$ (that is, if the reduction of product differentiation due to platform sharing is relatively small and the level of communication cost is also relatively small). Platform sharing reduces the level of product differentiation, which in turn induces more intense competition between the two manufacturers. Proposition 2 tells us that, from the consumers' standpoint, the former negative effect of platform sharing (the reduction of product variety) is offset by the latter positive effect (a lower price due to intense competition) when platform sharing increases the manufacturers' profits. Then, noting that each supplier's expected profit is zero due to free entry, platform sharing increases the total surplus as well.

Logic behind the result is as follows. Platform sharing intensifies the competition between the two manufacturers, which in turn reduces the share of total surplus captured by the two manufacturers as their aggregate profit. However, the level of their aggregate profit is higher under platform sharing if $x < \bar{x}$ and $z < z^*$ because the manufacturers choose to share a platform. This means that total surplus is higher under platform sharing, which in turn implies that consumer surplus is also higher because consumers capture larger share of total surplus under platform sharing.

4 An application to e-commerce

The rapid spread of electronic commerce, due to recent advances in information technology (IT revolution), is substantially changing the nature of manufacturer-supplier relationships. Kalakota and Robinson (2000) argue that the rise of Internet trading exchanges alters the process by which raw materials and supplies are procured and supply chains are integrated (see also Lucking-Reiley and Spulber (2001)). One important recent phenomenon in the Internet trading exchanges is the formation of industry consortiums for establishing business-to-business (B2B) electronic marketplaces. One of the most well-known consortiums is Covisint, which was founded by DaimlerChrysler, Ford, General Motors, Nissan, Renault, Commerce One and Oracle, and which launched the exchange in September 2000.[6] B2B electronic marketplaces such as Covisint can substantially reduce buyers' communication costs for exchanging detailed information with potential suppliers (see Introduction for an illustration).

In this section, we analyze an extension of our model that incorporates an option for the two manufacturers to jointly establish a B2B electronic marketplace (e-marketplace hereafter) in order to reduce their costs for communicating with potential suppliers, and explore its welfare implications. According to Jacob (2001), U.S. regulators are concerned about the possibility that e-marketplaces would facilitate collusion among buyer-participants, and suppliers' prices would be forced down to unacceptable levels as a consequence (see also Lucking-Reiley and Spulber (2001)).[7] In September 2001 the Federal Trade Commission completed its investigation to determine whether the formulation of Covisint violates the Clayton Act, which was the Commission's first investigation on electronic-procurement marketplaces. It permitted Covisint to proceed. At the same time, however, the Commission noted that it cannot say that implementation of the Covisint venture will not cause competitive concerns, and reserved the right to take such further actions as the public interest may require.[8] According to the Commission, "The growth of Internet-based electronic commerce

[6]According to the Covisint's web page, "Covisint is the central hub where OEMs and suppliers of all sizes come together to do business in a single business environment using the same tools and user interface, plus one user id and password" (http://www.covisint.com/about/, visited July 9, 2002). Other examples of B2B electronic marketplaces include Exostar in the aerospace and defense industry and Aeroxchange in the airline industry.

[7]Jacob also pointed out that large firms in Europe and Australia have also established e-marketplaces that have attracted similar regulatory attention.

[8]According to a press release by the FTC (available at http://www.ftc.gov/opa/2000/09/covisint.htm

is occurring so rapidly that the likely business and policy consequences are just beginning to be understood. Not surprisingly, scholarship is limited on the implications of e-commerce for competition policy."[9]

In this section we attempt to make a contribution to this important recent antitrust issue by proposing a theoretical framework for analysis. We consider the five-stage game described below, in which the two manufacturers can jointly establish an e-marketplace in order to reduce their communication costs.

[**Stage 1**] The two manufacturers jointly determine whether or not to establish an e-marketplace. If they do, each manufacturer i must incur a fixed cost $I > 0$.[10]

[**Stage 2**] Same as Stage 1 in the original model, where the two manufacturers jointly determine whether or not to share a platform of their products.

[**Stage 3**] Same as Stage 2 in the original model, where suppliers make entry decisions.

[**Stage 4**] Each manufacturer i determines the number of suppliers to communicate with, where each manufacturer i must incur communication cost $z(\geq 0)$ per supplier. The communication cost is given by $z = z_0 - \Delta$ if an e-marketplace was established at Stage 1, and

(visited July 9, 2002)), "... the Commission noted that, because Covisint is in the early stages of its development and has not yet adopted bylaws, operating rules, or terms for participant access, because it is not yet operational, and because its founders represent such a large share of the automobile market, the Commission cannot say that implementation of the Covisint venture will not cause competitive concerns."

[9]See The International Competition Policy Advisory Committee Final Report 2000 (available at http://www.usdoj.gov:80/atr/icpac/finalreport.htm (visited November 20, 2001)).

[10]Each manufacturer would not independently establish an e-marketplace for its own exclusive use by incurring a fixed cost of $2I$, even if we incorporated this as an option.

Lucking-Reiley and Spulber (2001) classify ownership of B2B e-marketplaces into three categories: independent firms that operate a website, traditional dealers who also operate on-line markets, and industry-operated exchanges. They argue that e-marketplaces for a few buyers and many suppliers tend to be owned by buyers (i.e., industry-operated exchanges). Consistent with this observation, we assume that it is the two manufacturers who invest in the establishment of an e-marketplace.

$z = z_0$ otherwise, where $z_0 \geq \Delta > 0$.[11]

[**Stage 5**] Same as Stage 4 in the original model, where Bertrand competition between the two manufacturers take place followed by procurement auctions.

As in the previous section, we consider the symmetric Subgame Perfect Nash Equilibria (SPNE) of each of the two Stage 3 subgames, and characterize an equilibrium of the entire game. We consider an equilibrium in which the two manufacturers jointly make decisions concerning an e-marketplace and platform sharing at Stages 1 and 2 respectively, so that each manufacturer's expected profit in the subsequent symmetric SPNE outcome is maximized. As in the previous section, we make Assumptions 1-3, where in this section we assume that Assumption 2 holds when $z = z_0$.

Proposition 3: For any given parameterization, there exists a unique value $\bar{I} > 0$ such that, in the equilibrium, the two manufacturers establish an e-marketplace if and only if $I < \bar{I}$, where $\bar{I}$ is increasing in Δ.

Proposition 3 simply says that the two manufacturers establish an e-marketplace if the required level of investment is relatively small. The threshold level of investment $\bar{I}$ increases as the reduction of the communication cost due to the e-marketplace (captured by Δ) increases.

We now turn to welfare implications of the establishment of an e-marketplace. We compare the Stage 2 subgame in which the two manufacturers established an e-marketplace at the previous stage (call it Marketplace Subgame) and the Stage 2 subgame in which the manufacturers did not establish it (call it non-Marketplace Subgame).

[11] Our model focuses on the reduction of the cost of procurement before the transaction. As pointed out by Lucking-Reiley and Spulber (2001), e-marketplaces also reduce the cost of procurement during and after the transaction. The qualitative nature of our results would be unchanged when the reduction of these costs are also incorporated into the model.

Proposition 4: Let $CS'(CS'')$ denote the consumer surplus in the equilibrium of the Stage 2 subgame in which the two manufacturers established (did not establish) an e-marketplace at the previous stage, and define TS' and TS'' analogously for expected total surplus. Then, $CS' \geq CS''$ and $TS' > TS''$ if $I < \bar{I}$.

From Proposition 3 we know that the two manufacturers will establish an e-marketplace if $I < \bar{I}$. Proposition 4 then tells us that, if the two manufacturers choose to establish an e-marketplace, the decision increases total surplus as well as consumer surplus.

A key to understanding this result is the way in which the establishment of an e-marketplace affects the manufacturers' decision concerning platform sharing. Recall that the establishment of an e-marketplace reduces each manufacturer's communication cost per supplier, which in turn increases the advantage of platform sharing. Hence, the establishment of an e-marketplace cannot induce the manufacturers to switch from platform sharing to non-platform sharing, and so we are left with the following three possibilities: (i) the two manufacturers do not share a platform in the non-Marketplace Subgame, while they share a platform in the Marketplace Subgame, (ii) the two manufacturers share a platform in both subgames, and (iii) the two manufacturers share a platform in neither subgame.

The analyses for cases (ii) and (iii) are straightforward. In these cases, the establishment of an e-marketplace does not affect the manufacturers' decision concerning platform sharing, and so does not alter the degree of product variety. Since the establishment of an e-marketplace reduces the manufacturers' expected procurement costs by inducing them to communicate with more potential suppliers, it increases consumer surplus in these cases. Then, noting that each supplier's expected profit is zero due to free entry, the establishment of an e-marketplace increases total surplus as well. In contrast, in case (i) the welfare implication is not immediately obvious because the establishment of an e-marketplace induces the manufacturers to switch from non-platform sharing to platform sharing, and this results in the reduction of product variety. However, through the same logic as the one presented after Proposition 2 in the previous section, we find that this negative effect on consumer surplus is offset by the positive effect of platform sharing due to more intense competition between the two manufacturers. Hence, in all three cases the establishment of an e-marketplace increases consumer surplus as well as total surplus.

The establishment of an e-marketplace could be viewed as an anticompetitive activity when accompanied by platform sharing, because it induces the manufacturers to reduce their procurement costs at the expense of reduced product variety. We found, however, that the establishment of an e-marketplace increases total surplus as well as consumer surplus in our model. One would find our theoretical framework suitable for investigating an industry in which cost structures of suppliers can be approximated by constant marginal cost and downstream manufacturers compete in the product market. Our analysis demonstrates that the establishment of e-marketplace can be welfare-enhancing in such an environment. On the other hand, one should apply a different theoretical framework for analyzing an industry in which the cost structure of suppliers is better approximated by increasing marginal cost and manufacturers attempt to exercise oligopsony power.

As a final point, another important issue concerning e-marketplaces is their impact on the organization of firms. Do e-marketplaces induce outsourcing and vertical disintegration? Our model can be extended to address this question. Suppose that each manufacturer has an option of producing parts internally with a constant marginal cost of $c \in (0, A)$. This means that the internal production is cost inefficient because the constant marginal cost of each supplier s is given by $c_s = c - \epsilon_s$. Assume that each manufacturer does not incur communication costs if it produces parts internally. In this setting, if the communication cost without e-marketplaces is sufficiently high and an e-marketplace substantially reduces the communication cost, the establishment of an e-marketplace induces outsourcing and vertical disintegration. This is consistent with Lucking-Reiley and Spulber (2001), who argue, "As market transaction costs fall with the maturation of business-to-business e-commerce, outsourcing and vertical disintegration will occur, resulting in more independent entities along the supply chain."

5 Summary and conclusion

This paper investigated the trade-off between commonality of components and the degree of product differentiation through analyzing a model that incorporates manufacturer-supplier relationships with communication costs into a standard differentiated duopoly model. In our model, the use of a common component (labelled as "platform sharing") reduces the degree of product differentiation. We found that, under platform sharing, each manufacturer can choose a supplier from a larger number of potential suppliers, which lowers its expected price for procurement. This is the advantage of platform sharing for manufacturers, and the advantage increases as the level of communication cost decreases. The result is that the two manufacturers share a platform if the reduction of product differentiation due to platform sharing is relatively small, and each manufacturer's cost for communicating with a potential supplier is relatively small as well. The second part of the result is due to the inverse relationship between the advantage of platform sharing and the level of communication cost. It is widely recognized that recent advances in information technology (IT revolution) can substantially reduce communication costs among firms. Our model suggests that the IT revolution could be a reason for the recent prevalence of platform sharing in the automobile industry, and predicts that similar phenomena would prevail in various other industries as the IT revolution makes further progress.

In order to further investigate the effect of the IT revolution, we analyzed an extension of our model that incorporates an option for the two manufacturers to jointly establish a B2B electronic marketplace (e-marketplace) in order to reduce their costs for communicating with potential suppliers, and explored its welfare implications. The establishment of an e-marketplace could be viewed as an anticompetitive activity when accompanied by platform sharing, because it induces the manufacturers to reduce their procurement costs at the expense of reduced product variety due to platform sharing. We found, however, that the establishment of an e-marketplace increases total surplus as well as consumer surplus even when it is accompanied by platform sharing. Platform sharing intensifies the competition between the manufacturers, which in turn reduces the share of total surplus captured by the manufacturers as their aggregate profit. However, the level of their aggregate profit is higher under platform sharing if they choose to share a platform. This means that total surplus is higher under platform sharing, which in turn implies that consumer surplus is also higher because consumers capture larger share of total surplus under platform sharing.

Antitrust investigations require that the key characteristics of the industry under investigation be properly taken into account. Our theoretical framework developed in this paper would be suitable for investigating an industry in which cost structures of suppliers can be approximated by constant marginal cost and downstream manufacturers compete in the product market. On the other hand, one should apply different models for analyzing an industry in which cost structures of suppliers are better approximated by increasing marginal cost and manufacturers attempt to exercise oligopsony power. In a future work, we plan to develop a model that is suitable for analyzing such an environment.

Appendix

We first present the proof of our results described in the second and the third paragraph of Section 3. Consider a Stage 4 subgame in which the two manufacturers did not share a platform at Stage 1, and at Stage 3 each manufacturer i communicated with $n_i(\geq 1)$ suppliers who specialized in part i at Stage 2. Suppose that each manufacturer i announced the price p_i such that $p_i > c+1$ at Stage 4, which determine the demand for each product q_i. Each manufacturer i procures q_i units of the common parts through a procurement auction, which can be translated into the following standard setting in auction theory: There is one seller who has an object to sell. The seller faces n_i bidders indexed by $l = 1, ..., n_i$. Each bidder l's value estimate for the object, denoted t_l, is known only to bidder l, and is independently and identically distributed according to a uniform distribution between $q_i(p_i - c)$ and $q_i(p_i - c + 1)$. The seller's personal value estimate for the object is common knowledge and given by $t_0 = 0$.

We apply Myerson (1981) (see in particular page 66-7), and obtain the following result: The seller's reserve price in an optimal auction is $Max[q_i(p_i - c), \frac{q_i(p_i - c+1)}{2}]$, which is equal to $q_i(p_i - c)$ because $p_i > c+1$. Then, in an optimal auction, the bidder with the highest valuation purchases the object. The expected amount of money the bidder pays to the seller is the second highest valuation among the n_i bidders if $n_i \geq 2$, and $q_i(p_i - c)$ if $n_i = 1$. This result indicates that, in our optimal procurement auction, each manufacturer i procures q_i units of the common part from a supplier who realized the lowest constant marginal cost, and that the expected price of the common part is equal to the second lowest realization of the constant marginal cost among the n_i suppliers if $n_i \geq 2$ and c if $n_i = 1$.

Let $\tilde{c}_i \in (0, A)$ denote the expected price at which manufacturer i purchases common parts in the procurement auction in the SPNE outcome of the Stage 3 subgame. Note that $\tilde{c}_i$ is each manufacturer i's expected constant marginal cost of production as well.

Then, the resulting Bertrand-Nash equilibrium prices of the stage 3 subgame are given by $p_i^* = \frac{(2+\gamma)(1-\gamma)A+2\tilde{c}_i+\gamma\tilde{c}_j}{4-\gamma^2}, i,j = 1,2, i \neq j, \gamma = \gamma_0$. Since $c-k$ is the lower bound for the realization of each supplier's constant marginal cost, $\tilde{c}_i > c-k$ holds in equilibrium. Assumption 3 then implies $p_i^* > c+1$. Then, the above analysis of the optimal procurement auction in the Stage 4 subgame indicates that $\tilde{c}_i = c - \frac{n_i-1}{n_i+1}k$ (i=1,2), which is the expected value of the second lowest realization of the constant marginal cost among the n_i suppliers if $n_i \geq 2$ and c if $n_i = 1$. This in turn implies that the SPNE outcome of the Stage 4 subgame is characterized by (3), (4) and (5) presented in the second paragraph of Section 3. Also, each supplier's expected profit in the SPNE outcome is $\pi_i^s(\gamma_0, n_i, n_j) - f$, which is defined by (6) in the third paragraph.

Next we present the proofs of the lemma and the propositions.

Proof of Lemma 1: We establish the following three claims:

Claim 1: There exists a unique real number, denoted $y^* \equiv n(\gamma, z)$, which is the unique solution to the following maximization problem:

$$\max_{y_i \geq 1} \pi_i^m(\gamma, z, y_i, y^*). \tag{9}$$

Proof of Claim 1: Consider the following maximization problem:

$$\max_{y_i \geq 1} \pi_i^m(\gamma, z, y_i, y_j), \tag{10}$$

where $y_j \geq 1$. We have

$$\frac{\partial^2}{\partial(y_i)^2}\pi_i^m(\gamma, z, y_i, y_j) = \frac{-8k(2-\gamma^2)}{(1-\gamma^2)(4-\gamma^2)}[\frac{1-\gamma}{2-\gamma}A - \frac{2-\gamma^2}{4-\gamma^2}(c-\frac{y_i-2}{y_i+1}k) + \frac{\gamma}{4-\gamma^2}(c-\frac{y_j-1}{y_j+1}k)]\frac{1}{(y_i+1)^3}, \tag{11}$$

and Assumption 3 implies that this second derivative takes a negative value for all $y_i \geq 1$ and $y_j \geq 1$. Hence, first order condition is necessary and sufficient for the interior maximum.

We have

$$\frac{\partial}{\partial y_i}\pi_i^m(\gamma,z,y,y)=\frac{4k(2-\gamma^2)}{(1+\gamma)(2-\gamma)(4-\gamma^2)}(A-c+\frac{y-1}{y+1}k)\frac{1}{(y+1)^2}-z. \quad (12)$$

Let $h(y)\equiv(A-c+\frac{y-1}{y+1}k)\frac{1}{(y+1)^2}$. Then $h'(y)=\frac{2}{(y+1)^3}[\frac{(2-y)k}{y+1}-(A-c)]$. Note $\frac{2+k-\gamma_0}{1-(\gamma_0+x)}>1+k>\frac{k}{2}$, which implies Assumption 3 $\Rightarrow \frac{k}{2}-(A-c)<0$. Hence, $h'(y)<0$ for all $y\geq 1$. Then, (i) there exists a unique real number $y>1$ such that $\frac{\partial}{\partial y_i}\pi_i^m(\gamma,z,y,y)=0$, or (ii) $\frac{\partial}{\partial y_i}\pi_i^m(\gamma,z,y,y)<0$ for all $y\geq 1$. This proves the claim. *Q.E.D.*

Claim 2: There exist unique values $n_c(\geq 1)$ and $n_d(\geq 1)$ such that $2\pi_i^s(\gamma_0+x,n_c,n_c)-f=0$ and $\pi_i^s(\gamma_0,n_d,n_d)-f=0$. Furthermore, $n_c>n_d\geq 1$.

Proof of Claim 2: We have $\pi_i^s(\gamma,y,y)=\frac{1}{(1+\gamma)(2-\gamma)}(A-c+\frac{y-1}{y+1}k)\frac{k}{y+1}\frac{1}{y}\equiv g(y)$. Note that $g(y)$ is continuous and strictly decreasing in y for all $y\geq 1$, because $g'(y)=\frac{-1}{(1+\gamma)(2-\gamma)}\frac{(2y+1)k}{[y(y+1)]^2}(A-c+\frac{y-1}{y+1}k-\frac{2y}{(2y+1)(y+1)}k)<0$ for all $y\geq 1$ by Assumption 3. Note also that $2\pi_i^s(\gamma_0+x,1,1)-f\geq 0$ and $\pi_i^s(\gamma_0,1,1)-f\geq 0$ by Assumption 1. These together imply the existence and uniqueness of $n_c(\geq 1)$ and $n_d(\geq 1)$. Also, we have $\frac{2}{(1+\gamma_0+x)[2-(\gamma_0+x)]}>\frac{1}{(1+\gamma_0)(2-\gamma_0)}$ for all $\gamma_0\in(0,1)$ and $x\in(0,1-\gamma_0)$. This implies $n_c>n_d$. *Q.E.D.*

Claim 3: Consider a Stage 2 subgame in which the two manufacturers shared (did not share) a platform at Stage 1. There exists a symmetric SPNE outcome in which the two manufacturers communicate with $\tilde{n}_c(z)\equiv Min[n(\gamma_0+x,z),n_c]$ ($\tilde{n}_d(z)\equiv Min[n(\gamma_0,z),n_d]$) suppliers, and no other symmetric SPNE outcomes.

Proof of Claim 3: Consider a Stage 2 subgame in which the two manufacturers did not share a platform at Stage 1.

(i) Suppose $n_d\leq n(\gamma_0,z)$. Consider a Stage 3 subgame in which n_d suppliers entered and specialized in part i (=1,2) at Stage 2. Noting that $\frac{\partial^2}{\partial(y_i)^2}\pi_i^m(\gamma_0,z,y_i,y_j)<0$ and $\frac{\partial^2}{\partial(y_j)^2}\pi_j^m(\gamma_0,z,y_i,y_j)<0$ for all $y_i\geq 1$ and $y_j\geq 1$, we have $\frac{\partial}{\partial y_i}\pi_i^m(\gamma_0,z,n_d,n_d)\geq 0$ and

$\frac{\partial}{\partial y_j}\pi_j^m(\gamma_0, z, n_d, n_d) \geq 0$. This implies that each manufacturer i communicates with n_d suppliers in the SPNE outcome of the Stage 3 subgame. Note that $\pi_i^s(\gamma_0, n_d, n_d) - f = 0$ holds, and that we have

$$\frac{\partial}{\partial y_i}\pi_i^s(\gamma, y_i, y_j) = \frac{-2y_i - 1}{[y_i(y_i+1)]^2}[\frac{1-\gamma}{2-\gamma}A - \frac{2-\gamma^2}{4-\gamma^2}(c - \frac{y_i - 1}{y_i + 1}k + \frac{1}{y_i+1}\frac{2y_i}{2y_i+1}k) + \frac{\gamma}{4-\gamma^2}(c - \frac{y_j - 1}{y_j + 1}k)], \tag{13}$$

where Assumption 3 implies $\frac{\partial}{\partial y_i}\pi_i^s(\gamma, y_i, y_j) < 0$ for all $y_i \geq 1$ and $y_j \geq 1$. Hence, the Stage 2 subgame has a symmetric SPNE outcome in which n_d suppliers enter and specialize in part i (=1,2) at Stage 2 and each manufacturer i communicates with n_d suppliers at Stage 3. Also, if $n(\neq n_d)$ suppliers enter and specializes in part i (=1,2) at Stage 2, each supplier's expected profit in the subsequent SPNE outcome of the Stage 3 subgame is not zero. Hence, there are no other symmetric SPNE outcomes of the Stage 2 subgame.

(ii) Suppose $n_d > n(\gamma_0, z)$. Note that $\pi_i^s(\gamma_0, n(\gamma_0, z), n(\gamma_0, z)) - f > 0$. Define n' by

$$\frac{1}{(1+\gamma_0)(2-\gamma_0)}(A - c + \frac{n(\gamma_0, z) - 1}{n(\gamma_0, z) + 1}k)\frac{k}{n(\gamma_0, z) + 1}\frac{1}{n'} - f = 0. \tag{14}$$

Note that n' is unique and $n' > n(\gamma_0, z)$. Consider a Stage 3 subgame in which n' suppliers entered and specialized in part i (=1,2) at Stage 2. Since $n' > n(\gamma_0, z)$, each manufacturer i communicates with $n(\gamma_0, z)$ suppliers in the symmetric SPNE outcome of the Stage 3 subgame. This in turn means that the Stage 2 subgame has a symmetric SPNE outcome in which n' suppliers enter and specialize in part i (=1,2) at Stage 2 and each manufacturer i communicates with $n(\gamma_0, z)$ suppliers at Stage 3. Also, through the same reasoning as in (i) above, there are no other symmetric SPNE outcomes of the Stage 2 subgame.

This completes the proof for the Stage 2 subgame in which the two manufacturers did not share a platform at Stage 1. The proof for the other subgame is analogous. *Q.E.D.*

Claim 3 implies Lemma 1. *Q.E.D.*

Proof of Proposition 1: Let $\pi_c(z) \equiv \pi_i^m(\gamma_0+x, z, \tilde{n}_c(z), \tilde{n}_c(z))$ and $\pi_d(z) \equiv \pi_i^m(\gamma_0, z, \tilde{n}_d(z), \tilde{n}_d(z))$, where $\pi_i^m(\gamma, z, n, n) = \frac{1-\gamma}{(1+\gamma)(2-\gamma)^2}(A-c+\frac{n-1}{n+1}k)^2 - nz$. We first establish the following claim.

Claim 4: There exists a unique real number $\bar{x} \in (0, 1-\gamma_0)$ such that $\pi_c(0) > \pi_d(0)$ if and only if $x < \bar{x}$.

Proof of Claim 4: First note that $n(\gamma, z) \to +\infty$ as $z \to 0$. Hence, if $z = 0$, $\tilde{n}_c(z) = n_c$ and $\tilde{n}_d(z) = n_d$. We have $\pi_i^m(\gamma, 0, n, n) = \frac{1-\gamma}{(1+\gamma)(2-\gamma)^2}(A-c+\frac{n-1}{n+1}k)^2$. Note that $n_c > n_d \geq 1$ (see Claim 2), which implies $\pi_i^m(\gamma_0, 0, n_c, n_c) > \pi_i^m(\gamma_0, 0, n_d, n_d) > \pi_i^m(1, 0, n_c, n_c) = 0$. We have $\frac{d}{d\gamma}[\frac{1-\gamma}{(1+\gamma)(2-\gamma)^2}] = -\frac{2(2-\gamma)(\gamma^2-\gamma+1)}{(1+\gamma)^2(2-\gamma)^4} < 0$ for all $\gamma \in (0,1)$, which implies that $\pi_i^m(\gamma_0+x, 0, n_c, n_c)$ is continuous and strictly decreasing in x for all $x \in (0, 1-\gamma_0)$. This proves the claim. *Q.E.D.*

Next, we identify some properties of $n(\gamma, z)$. As shown in the proof of Claim 1, if $n(\gamma, z) > 1$, $n(\gamma, z)$ is uniquely determined by

$$\frac{4k(2-\gamma^2)}{(1+\gamma)(2-\gamma)(4-\gamma^2)} h(n(\gamma, z)) - z = 0, \tag{15}$$

where $h(y) \equiv (A-c+\frac{y-1}{y+1}k)\frac{1}{(y+1)^2}$. Since $h'(y) < 0$ for all $y \geq 1$, $n(\gamma, z)$ is continuous in z and exhibits the following property: There exist unique real numbers $\tilde{z}_c(>0)$ and $\tilde{z}_d(>0)$ such that

(i) $n(\gamma_0+x, z) = 1$ for all $z \geq \tilde{z}_c$, $n(\gamma_0+x, z)$ is strictly decreasing in z for all $z < \tilde{z}_c$, and $n^*(\gamma_0+x, 0) = +\infty$.

(ii) $n(\gamma_0, z) = 1$ for all $z \geq \tilde{z}_d$, $n(\gamma_0, z)$ is strictly decreasing in z for all $z < \tilde{z}_d$, and $n(\gamma_0, 0) = +\infty$.

Note that $\frac{d}{d\gamma}[\frac{2-\gamma^2}{(1+\gamma)(2-\gamma)(4-\gamma^2)}] = \frac{-8+8\gamma+2\gamma^2-8\gamma^3-\gamma^4+2\gamma^5}{[(1+\gamma)(2-\gamma)(4-\gamma^2)]^2} < 0$ for all $\gamma \in [0,1]$. We then have $\frac{2-\gamma_0^2}{(1+\gamma_0)(2-\gamma_0)(4-\gamma_0^2)} > \frac{2-(\gamma_0+x)^2}{(1+\gamma_0+x)[2-(\gamma_0+x)][4-(\gamma_0+x)^2]}$, which implies $\tilde{z}_d > \tilde{z}_c(>0)$ and $n(\gamma_0, z) > n(\gamma_0+x, z)$ for all $z < \tilde{z}_d$. This in turn means that there exist unique values z_c and z_d

$(0 < z_c < z_d)$ such that $n_c < n(\gamma_0 + x, z)$ if and only if $z < z_c$ and $n_d < n(\gamma_0, z)$ if and only if $z < z_d$.

We now establish Claim 5 below, which completes the proof of Proposition 1.

Claim 5: Define $\bar{x}$ as in Claim 4.

(i) if $x > \bar{x}$, $\pi_c(z) < \pi_d(z)$ for all $z \in [0, \bar{z})$.

(ii) if $x < \bar{x}$, there exists a unique value $z^* \in (0, \bar{z}]$ such that $\pi_c(z) > \pi_d(z)$ if and only if $z < z^*$. There exists a range of parameterizations in which $z^* < \bar{z}$ holds.

Proof of Claim 5: First note that $\pi_c(z)$ and $\pi_d(z)$ are continuous and strictly decreasing in z for all $z \in [0, \bar{z})$. Suppose $x < \bar{x}$. Then there exists a unique real number $z^* \in (0, \bar{z}]$ such that $\pi_c(z) > \pi_d(z)$ for all $z \in [0, z^*)$ and $\pi_c(z^*) = \pi_d(z^*)$ if $z^* < \bar{z}$.

Pick any $z \in (0, \bar{z})$. Note that $n_c \to +\infty$ and $n_d \to +\infty$ as $f \to 0$. Then, holding all parameter values except f fixed, we can pick small enough $f > 0$ such that $\tilde{n}_c(z) = n(\gamma_0 + x, z)$ and $\tilde{n}_d(z) = n(\gamma_0, z)$. Then, $\frac{1-\gamma_0}{(1+\gamma_0)(2-\gamma_0)^2} > \frac{1-(\gamma_0+x)}{(1+\gamma_0+x)[2-(\gamma_0+x)]^2} \Rightarrow \pi_c(z) < \pi_d(z)$. This implies that there exists a range of parameterizations in which $z^* < \bar{z}$ holds.

In what follows, we will show that $\pi_c(z) < \pi_d(z)$ for all $z \in (z^*, \bar{z})$ if $z^* < z_c$.

(i) $n_d < n_c \Rightarrow \pi_c(z) < \pi_d(z)$ for all $z \in (z^*, z_c]$.

(ii) Consider $z \in (z_c, z_d)$. If $n(\gamma_0 + x, z) \leq n_d$, we have $\pi_i^m(\gamma_0, z, n_d, n_d) \geq \pi_i^m(\gamma_0, z, n(\gamma_0 + x, z), n(\gamma_0 + x, z)) > \pi_i^m(\gamma_0 + x, z, n(\gamma_0 + x, z), n(\gamma_0 + x, z))$, which implies $\pi_c(z) < \pi_d(z)$.

Now, pick any $z' \in (z_c, z_d)$ such that $n(\gamma_0 + x, z') > n_d$, and pick any $z'' \in (z^*, z_c)$. Suppose $\pi_c(z') \geq \pi_d(z')$. Note that $\pi_c(z'') > \frac{1-(\gamma_0+x)}{(1+\gamma_0+x)[2-(\gamma_0+x)]^2}(A - c + \frac{n(\gamma_0+x,z')-1}{n(\gamma_0+x,z')+1}k)^2 - n(\gamma_0 + x, z')z'' \equiv \tilde{\pi}_c(z'')$. We have $(\tilde{\pi}_c(z'') - \pi_c(z')) - (\pi_d(z'') - \pi_d(z')) = (n(\gamma_0 + x, z') - n_d)(z' - z'') > 0$. Then, $\pi_c(z'') > \tilde{\pi}_c(z'')$ and $\pi_c(z') \geq \pi_d(z')$ together imply $\pi_c(z'') > \pi_d(z'')$. This is a contradiction to (i), and so $\pi_c(z') < \pi_d(z')$ must hold. This in turn implies $\pi_c(z) < \pi_d(z)$ for all $z \in (z_c, z_d)$.

(iii) We have $\pi_i^m(\gamma_0 + x, z, n(\gamma_0 + x, z), n(\gamma_0 + x, z)) < \pi_i^m(\gamma_0, z, n(\gamma_0, z), n(\gamma_0, z))$ for all $z \in [0, \bar{z})$, which implies $\pi_c(z) < \pi_d(z)$ for all $z \in [z_d, \bar{z})$.

(i)-(iii) together imply $\pi_c(z) < \pi_d(z)$ for all $z \in (z^*, \bar{z})$ if $z^* < z_c$. Through a similar procedure, it can be shown that the same result holds if $z^* \geq z_c$.

Finally, suppose $x > \bar{x}$. Through a similar procedure, it can be shown that $\pi_c(z) < \pi_d(z)$ for all $z \in [0, \bar{z})$. This completes the proof of the claim and the proposition. *Q.E.D.*

Proof of Proposition 2: Consider the symmetric SPNE outcome of the Stage 2 subgame in which the two manufacturers shared a platform at Stage 1. In the equilibrium, each manufacturer i sells $q_i(\gamma_0 + x, \tilde{n}_c(z), \tilde{n}_c(z)) \equiv q_c$ units of product i at the price of $p_i(\gamma_0 + x, \tilde{n}_c(z), \tilde{n}_c(z))$. Then, we find $CS_c = (1 + \gamma_0 + x)q_c^2 = CS(\gamma_0 + x, \tilde{n}_c(z))$, where

$$CS(\gamma, n) \equiv \frac{1}{(1+\gamma)(2-\gamma)^2}(A - c + \frac{n-1}{n+1}k)^2. \tag{16}$$

Analogously, $CS_d = CS(\gamma_0, \tilde{n}_d(z))$. Note that $\frac{d}{d\gamma}[\frac{1}{(1+\gamma)(2-\gamma)^2}] = \frac{3\gamma(2-\gamma)}{[(1+\gamma)(2-\gamma)^2]^2} > 0$ for all $\gamma \in (0, 1]$, and so $\frac{1}{(1+\gamma_0+x)[2-(\gamma_0+x)]^2} > \frac{1}{(1+\gamma_0)(2-\gamma_0)^2}$. Note also, $x < \bar{x}$ and $z < z^* \Rightarrow \pi_c(z) > \pi_d(z) \Rightarrow \tilde{n}_c(z) > \tilde{n}_d(z)$. Hence, we find $CS(\gamma_0 + x, \tilde{n}_c(z)) > CS(\gamma_0, \tilde{n}_d(z))$. Since suppliers' expected profits are zero in the equilibrium, $\pi_c(z) > \pi_d(z)$ and $CS_c > CS_d$ together imply $TS_c > TS_d$ if $x < \bar{x}$ and $z < z^*$. *Q.E.D.*

Proof of Proposition 3: Define $\Pi_m(z) \equiv Max[\pi_c(z), \pi_d(z)]$, which is strictly decreasing in z for all $z \in [0, \bar{z})$ because $\pi_c(z)$ and $\pi_d(z)$ are both strictly decreasing in z for all $z \in [0, \bar{z})$. In the equilibrium of the entire game, the two manufacturers establish an e-marketplace if $\Pi_m(z_0 - \Delta) - I > \Pi_m(z_0)$. Define $\bar{I} \equiv \Pi_m(z_0 - \Delta) - \Pi_m(z_0) (> 0)$, and we obtain the desired result. *Q.E.D.*

Proof of Proposition 4: First note that free entry of suppliers implies that each supplier's expected profit is zero in the equilibrium. Suppose $I < \bar{I}$. Since $\Pi_m(z_0 - \Delta) - I > \Pi_m(z_0)$ holds, $CS' \geq CS'' \Rightarrow TS' > TS''$. In what follows, we prove $CS' \geq CS''$. Proposition 1 implies that the following three cases exhaust all possible cases.

Case 1: The two manufacturers share a platform in the equilibrium of neither subgame. In this case, $CS' = CS(\gamma_0, \tilde{n}_d(z_0 - \Delta))$ and $CS'' = CS(\gamma_0, \tilde{n}_d(z_0))$, where $CS(\cdot, \cdot)$ is as defined in the proof of Proposition 2. Noting that $\tilde{n}_d(z)$ is (weakly) decreasing in z, we have $CS' \geq CS''$.

Case 2: The two manufacturers share a platform in the equilibrium of both subgames. In this case, $CS' = CS(\gamma_0 + x, \tilde{n}_c(z_0 - \Delta))$ and $CS'' = CS(\gamma_0 + x, \tilde{n}_c(z_0))$. Noting that $\tilde{n}_c(z)$ is (weakly) decreasing is z, we have $CS' \geq CS''$.

Case 3: The two manufacturers share (do not share) a platform in the equilibrium of Marketplace subgame (non-Marketplace subgame). In this case, $CS' = CS(\gamma_0 + x, \tilde{n}_c(z_0 - \Delta))$ and $CS'' = CS(\gamma_0, \tilde{n}_d(z_0))$. Noting $\frac{1}{(1+\gamma_0+x)[2-(\gamma_0+x)]^2} > \frac{1}{(1+\gamma_0)(2-\gamma_0)^2}$, $\tilde{n}_c(z_0 - \Delta) > \tilde{n}_d(z_0) \Rightarrow CS' > CS''$.

Claim 6: In case 3, $\tilde{n}_c(z_0 - \Delta) > \tilde{n}_d(z_0)$ holds.

Proof of Claim 6: Since $\tilde{n}_d(z)$ is (weakly) decreasing in z, it suffices to show $\tilde{n}_c(z_0 - \Delta) > \tilde{n}_d(z_0 - \Delta)$. Suppose, to the contrary, $\tilde{n}_c(z_0 - \Delta) \leq \tilde{n}_d(z_0 - \Delta)$. Then, $\pi_i^m(\gamma_0, z_0 - \Delta, \tilde{n}_d(z_0 - \Delta), \tilde{n}_d(z_0 - \Delta)) \geq \pi_i^m(\gamma_0, z_0 - \Delta, \tilde{n}_c(z_0 - \Delta), \tilde{n}_c(z_0 - \Delta)) > \pi_i^m(\gamma_0 + x, z_0 - \Delta, \tilde{n}_c(z_0 - \Delta), \tilde{n}_c(z_0 - \Delta))$. This is a contradiction, because, in case 3, the two manufacturers share a platform in the equilibrium of Marketplace subgame. *Q.E.D.*

Hence, $CS' \geq CS''$ holds in all three cases. This completes the proof of the proposition. *Q.E.D.*

References

Corbett, B. and A. Wielgat, 2000, “Fiat, GM Ripe with Overlap”, *Ward’s Auto World*, 36, pp. 37.

Dixit, A.K., 1979, “A Model of Duopoly Suggesting a Theory of Entry Barriers”, *Bell Journal of Economics*, 10, pp. 20-32.

Jacobs, M.S., 2001, “Second Order Oligopoly Problems with International Dimensions: Sequential Mergers, Maverick Firms and Buyer Power”, *The Antitrust Bulletin*, 46, pp. 537-568.

Kalakota, R. and M. Robinson, 2000, *e-Business 2.0: Roadmap for Success*, Addison-Wesley.

Kauffman, R.J. and E.A. Walden, 2001, “Economics and Electronic Commerce: Survey and Directions for Research”, *International Journal of Electronic Commerce*, 5, pp. 5-116.

Kranton, R.E. and D.F. Minehart, 2001, “A Theory of Buyer-Seller Networks”, *American Economic Review*, 91, pp. 485-508.

Lucking-Reiley, D. and D.F. Spulber, 2001, “Business-to-Business Electronic Commerce”, *Journal of Economic Perspectives*, 15, pp. 55-68.

Myerson, R.B., 1981, “Optimal Auction Design”, *Mathematics of Operations Research*, 6, pp. 58-73.

Pepall, L. and G. Norman, 2001, “Product Differentiation and Upstream-Downstream Relations”, *Journal of Economics and Management Strategy*, 10, pp. 201-233.

Robertson, D. and K. Ulrich, 1998, “Planning for Product Platforms”, *Sloan Management Review*, 39, pp. 19-31.

Singh, N. and X. Vives, 1984, "Price and Quantity Competition in a Differentiated Duopoly", *Rand Journal of Economics*, 15, pp. 546-554.

Tierney, C., A. Bawden, and M. Kunii, 2000, "Dynamic Duo", *Business Week*, October 23, pp. 26.